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Artificial Intelligence and Green Finance: Unveiling the Link to Financial Performance in Pakistan

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Abstract

This paper examines the effectiveness of artificial intelligence (AI) adoption and green finance, as well as their impact on the financial performance of firms in the green finance sector in Pakistan over the period 2014-2023. As more people become globally aware of sustainability and the environment, green finance, facilitated by AI, can transform the process of making financial decisions to build investment portfolios. The study examined the impact of AI-driven methods in green finance (i.e., green bond issuance, Regularity strength, ESG incorporation, and carbon footprint reduction) on financial performance metrics. Financial performance is measured by Return on Assets (ROA). Based on the information collected with the assistance of financial institutions in Pakistan, the researcher employed the Generalized Method of Moments (GMM) estimation approach to address potential endogeneity problems. The results suggest that the adoption of AI, strength of regulation, the issuance of green bonds, and ESG scores has a positive and significant effects on financial performance, and the strength of regulatory presence enhances the positive effect of AI. These findings suggest a greater relevance of AI in enhancing the financial performance of institutions that adhere to the principles of sustainable finance, as well as in achieving the overall objective of environmental sustainability. The study has important implications for policymakers, investment companies, and financial institutions that seek to incorporate AI technology into their green finance plans to develop more effective financial and environmental solutions.

INTRODUCTION

Artificial intelligence (AI) in green finance is a new phenomenon that is already becoming a game-changer in the world of finance, as it can help to ensure the sustainable development of the economy and address existing global environmental problems. AI has become one of the most valuable resources for improving decision-making processes, risk management, and operational effectiveness in most industries. Indeed, the idea of implementing AI technologies in the context of such a contextually relevant activity as green finance is particularly important because it enables financial institutions to assess prospects and make decisions about investments in environmentally sound projects more precisely (Zeb et al., 2025). Green finance refers to the services and products of the financial sector that aim to positively influence environmental sustainability, such as green bonds, renewable energy projects, and investments in sustainable infrastructure (Zhou et al., 2020). The concept

of green finance has gained significant popularity as the world strives to achieve sustainability and climate goals. The transition to a low-carbon economy requires substantial investment in environmentally friendly initiatives, which are now being funded with the support of green bonds and other green finance-friendly instruments provided by financial institutions. With the evolution of financial markets, the role of artificial intelligence (AI) in creating a green finance optimization process has become increasingly clear (Ali et al., 2025). Artificial intelligence (AI) is one of the new technologies that can help to make a more environmentally, socially, and governance (ESG) accurate assessment of investment performance and financial operations, in general, is machine learning, data analytics, and natural language processing.

The most recent innovations in AI have transformed the financial sector, enhancing decision-making capacities to drive more effective risk management and improve judgment of financial products (Choi et al., 2021). The application of AI in green finance is also instrumental in optimizing investment choices, enhancing green bond pricing models, refining ESG analysis, and automating risk calculation in sustainable investments (Nguyen et al., 2022). Although the aforementioned are the advantages of implementing AI in green finance, the realization process of implementing it in green finance is still in its infancy, especially in the developing world, where the technological infrastructure may be underdeveloped and the green finance regulatory framework is still underdeveloped.

Pakistan, being one of the developing economies, is having some peculiar challenges and opportunities during the implementation of AI-based green financial solutions. On the one hand, the country is extremely susceptible to the effects of climate change, including extreme weather patterns and an increase in water levels (Ali et al., 2020). In contrast, Pakistan remains relatively underexploited in the fields of renewable energy, green infrastructure, and sustainable development solutions, which are aligning with the global trend towards the adoption of AI in financial decision-making (Khan et al., 2021). The Pakistani government has taken steps to advance green finance by implementing policies that favor the development of more climate-smart infrastructure and renewable energy investments (Siddiqi & Imran, 2020). Yet, not much effort has been undertaken in applying AI to these activities, especially when it comes to automating workflows for issuing green bonds and evaluating their ESG ratings.

Banks and other financial institutions in Pakistan (including insurance and asset management firms) have started to consider the use of artificial intelligence to enhance their efficiency during operations and the consistency of their portfolios with sustainable development aims (SDGs). Nevertheless, the effectiveness of AI applications in green finance depends on a set of factors, such as the adequacy of regulation, market drivers, and institutional preparedness. The key factor in the success of AI-driven financial solutions is the creation of a robust regulatory framework that encourages the use of AI and promotes green finance. According to Shafique et al. (2022), the regulatory landscape of green finance in Pakistan is developing yet remains imperfect, particularly in terms of ensuring ESG standards globally and driving innovation in financial instruments. The objective of this study is to assess the effectiveness of adoption on the financial outcomes of financial institutions in Pakistan, where green finance is prevalent. The primary hypothesis of this paper is that the application of AI in green finance has a positive impact on financial performance, as AI can enhance the efficiency of financial products related to green finance,

including green bonds and ESG funds. It is hypothesized that regulatory strength will further solidify this relationship by providing an enabling environment for the implementation of AI in financial institutions. This literature remains a niche area in terms of research, and this paper contributes to it by investigating the implications of AI adoption on financial performance in the context of a developing country. Although previous studies focused on advanced economies, the present study contributes to understanding the current situation regarding the impact of AI on the financial performance of institutions in Pakistan's emerging economy. It also demonstrates the significance of regulatory capacity in establishing an enabling condition for AI application in the green finance sector, especially in climate-sensitive economies, which have a high susceptibility to climate change and a high dependency on green finance.

Moreover, this study has significant policy implications for Pakistani financial regulators, institutional investors, and green finance practitioners. Knowledge about the correlation between AI adoption and financial performance in the green finance industry can inform the formulation of new policies favorable toward innovation in AI applications in the financial industry, which in turn would lead to the achievement of SDGs in Pakistan and its climate-related pursuits. Although attention to the role of AI in financial markets has been increasing, a relatively limited number of studies have been devoted to questions of AI application in the context of green finance. The smaller number of studies has addressed the relationship in developing countries, where economic growth, technological innovation, and green finance complexities present distinct challenges and opportunities (Gao et al., 2021). The specified research has filled this gap by analyzing the global problem of the repercussions of AI adoption on financial performance in the green finance sector in Pakistan, providing reasonable insights not only to a community of researchers but also to practitioners, such as economists in the sustainable finance department.

LITERATURE REVIEW

The literature review focuses on recent studies on artificial intelligence (AI) in green finance and its impact on financial performance in developing countries such as Pakistan. This study draws upon research in the spheres of AI application in finance and green finance to inform the discussion of AI as a driver of sustainability and financial performance. AI technologies have played a critical role in transforming financial services improving the decisions, efficiency, and profitability of most financial goods and services. The extent of research on the contribution of AI to improving financial performance, particularly in asset management, investment analysis, and risk management, has been increasing.

Technologies such as predictive analytics, machine learning (ML), natural language processing (NLP) and robotic process automation (RPA) are also applications of AI in the banking industry. According to Barcanescu (2020), AI has enhanced the data-based decision-making of financial institutions, improved client experience, and reduced operating costs. The positive implications of AI use by financial institutions were the focus of Choi et al., (2021), who stated that AI can enhance the efficiency of decision-making, thereby improving the institution's performance. Exposure to these financial operations has led to increased profits and a competitive advantage for institutions that effectively utilize AI technology. Patients are considered at higher risk due to underlying health conditions, even if the overall level of risk remains relatively low. The AI algorithms can assess credit, market, and liquidity risk in ways that traditional models cannot. In green finance, machine learning, as one of the AI-based

tools, can provide an assessment of the sustainability risks associated with green projects and investments, resulting in reduced investment risks and increased profits (Binns et al., 2021). It is generally appreciated how AI can affect the area of financial efficiency. It enables the improved optimization of portfolios, which has been linked to better returns on investments and more effective fund allocation. Artificial intelligence can identify discounted sustainable investment opportunities, thereby enhancing the financial outcomes of organizations that have made a sustainability pledge. Nguyen et al., (2022) demonstrated that firms using AI-powered analytics in portfolio management achieve better returns and are exposed to smaller levels of risk, resulting in improved overall financial outcomes.

Green Finance and Financial Performance

Green finance is a term that defines the financial tools and services supporting actions aimed at addressing environmental impacts, such as green bonds, ESG investments, and renewable energy financing. With a more sustainable economy emerging globally, green finance has garnered increased attention due to its ability to generate financial returns while addressing environmental challenges.

Many researchers confirm that green finance initiatives can positively impact the financial operations of companies and organizations. Participation in green finance operations may result in fewer operational risks for the financial institution, along with strong brand awareness, and subsequently greater long-term profitability. Companies that offer green bonds and pay significant attention to sustainable investments often have easier access to financing and more favorable investment terms (Tariq et al., 2020). Furthermore, green solutions to finance will attract socially responsible investors, which promote market performance and raises shareholder value (Yu et al., 2023).

In countries like Pakistan, which are poor, green financing is still in its early stages of development. However, it has a lot of potential in helping to overcome environmental-related problems, providing gainful employment, and promoting sustainable economic growth. Ali et al., (2020) stated that green finance plays a significant role in supporting renewable energy, water conservation, and sustainable agriculture activities in Pakistan. Shafique et al., (2022) argue that financial institutions in Pakistan face specific limitations, including weak legal frameworks and limited access to technical knowledge, which prevent the widespread adoption of green finance methods. Still, with green financial instruments, including green bonds, financial performance can be significantly improved while also meeting international sustainability goals (Siddiqi & Imran, 2020).

Artificial Intelligence and Green Finance

Artificial intelligence and sustainable finance are emerging areas of research. Artificial intelligence would also have the potential to complement the effectiveness of green finance tools by enhancing sustainability ratings, reducing risk, and improving investment efficiency. Artificial intelligence will help increase the evaluation and quality of green bonds by analyzing market trends, environmental impact, and key financial performance indicators (Zhou et al., 2020). Nguyen et al., (2022) emphasized that green projects have environmental risks and rewards that can be predicted using machine learning models as inputs into climate-related capital allocation decisions used in green finance products. Additionally, the openness and accountability of green finance investments can be improved with the help of AI, which is a critical tool to assure investors of the environmental and social implications of their investments (Binns et al., 2021). Integrating AI into Environmental, Social, and Governance (ESG)

analysis would enable financial institutions to assess the sustainability performance of potential investments more effectively. With the assistance of AI, large data volumes can be analyzed to identify ESG risks, track carbon footprints, and assess climate-related disclosures that extend beyond the scope of traditional methods (Pereira et al., 2021). This contributes to the effectiveness and accuracy of ESG ratings, which are increasingly crucial to investors who want to align their portfolios with the Sustainable Development Goals (SDGs). The automation of ESG reporting and data quality, facilitated by AI, could therefore have tangible benefits for the financial performance of organizations engaging in green finance (Choi et al., 2021).

Regulatory Environment and AI Adoption

The situation with green finance and the introduction of AI depends not only on technological advancements but also on the legislative system. Governments and regulators play a vital role in enhancing the adoption of AI in the green finance sector by facilitating decades of research, rewards, and structure. Countries like Pakistan that require green financing are still in the development stage of establishing regulatory frameworks to govern green financing. Khan et al., (2021) outlined the need to implement green finance policies that should encourage investment in climate-resilient and renewable energy infrastructure. The slipshod approach to adopting AI in green finance can, however, be attributed to the legislative deficit of most developing countries. Shafique et al., (2022) argued that comprehensive regulation could encourage financial institutions to focus on green initiatives by setting clear guidelines for issuing green bonds and engaging in sustainable investment activities.

Among the ways that governments can enhance the effectiveness of AI adoption in green finance include crafting data protection laws, developing AI ethical guidelines, and establishing transparency models (Siddiqi & Imran, 2020). Governments can help increase investor confidence in green finance products that rely on artificial intelligence by providing clear regulatory guidelines, which in turn helps institutions reduce the risk associated with adopting AI.

Green Innovation and Technological Advancements

In conclusion, technological advancement, such as AI, may act as a mitigation factor and contribute to the adoption of sustainable behaviors in the financial sector. With the help of AI, financial institutions that implement green innovation can develop new financial products that align with their environmental goals. Companies that utilize AI to promote green finance often deliver high returns and organizational growth on the market (Tariq et al., 2020). With the help of AI in green finance products, financial institutions will have access to new markets, can increase the efficiency of their operations, and contribute to environmental sustainability. This technical advancement has created a system of green innovation-friendly environment, which has led to financial feasibility and long-standing effect.

It has been established in the literature that green finance can be improved through better investment efficiency, risk management, and transparency achieved by integrating AI into green finance. Moreover, the legislative framework is crucial in facilitating the integration of AI into financial operations. Although Pakistan faces challenges, AI can revolutionize the green finance sector, creating not only ecological prosperity but also economic growth. The research will explore the prediction of how AI can improve decision-making and investment patterns in green finance, particularly in emerging economies.

THEORETICAL FRAMEWORK

The theoretical background of the studies on the role of artificial intelligence (AI) in promoting green finance and enhancing financial performance is grounded in multiple related concepts, primarily based on technological innovation, sustainable finance, and models of financial performance. Such a strategy explains why green finance AI technologies can enhance financial performance and bring sustainability. The following are the main hypotheses that support this study.

Technology Acceptance Model

One of the most fundamental understandings of how consumers accept and adopt technology is provided by the Technology Acceptance Model (TAM), developed by Davis in 1989. TAM proposes that the ease of use of the technology and the usefulness of such resources are key drivers that influence the adoption of new technologies. The model suggests that in countries like Pakistan, financial institutions will adopt AI in green finance if they perceive it as easy to adapt and beneficial in terms of improving operations, performance, and financial decision-making. To make AI widely acceptable in green finance, institutions need to recognize that technology can generate measurable financial benefits while also supporting the restoration of the environment to its natural state. The involvement of AI in green finance can increase financial performance because the perceived usefulness and ease of application define investment decisions and improve risk management in green finance endeavors.

Resource-Based View

The Resource-Based View (RBV) of the firm, as presented by Barney (1991), posits that organizations can achieve a competitive advantage by acquiring, absorbing, and leveraging desirable, rare, unique, and valuable resources. Within this view, AI is regarded as a tactical resource capable of enhancing the competitive position of financial entities.

Green finance, facilitated by artificial intelligence, enables companies to efficiently utilize available cash for sustainable projects, conduct accurate and effective risk assessments, and refine their investment strategies. AI can also improve financial performance, as such technologies will enable institutions to gain a deeper understanding of market patterns, predict investment returns, and manage ESG-related risks more efficiently. By incorporating AI into their operations, banks can achieve a sustainable competitive advantage in green financing. The employment of AI in green finance helps to improve financial performance, as well as provide a competitive advantage due to its high degrees of decision-making capabilities, operations, and risk management.

Theory of Stakeholders

Stakeholder Theory was developed by Freeman (1984), who assumed that all stakeholders, not just shareholders, must be taken into consideration when making business decisions. The stakeholders in green finance include investors, customers, regulatory agencies, and society, all of whom are very concerned with the sustainability of the environment.

Green finance, integrated with AI, enhances shareholder value through increased transparency, improved accounting, and enhanced ESG performance. AI will be

able to help financial institutions accurately record their environmental impact, consequently boosting stakeholder confidence. Moreover, the green finance movement, powered by AI, allows for improving the efficiency of resource allocation, eliminating environmental issues, and contributing to sustainable development. Green finance involving AI would positively influence stakeholder satisfaction, as it would increase ESG performance, ultimately leading to improved financial performance of the institution.

Efficient Market Theory (EMH)

Another popular financial model is by Fama (1970), which holds the Efficient Market Hypothesis (EMH), which asserts that all data that is available financial market is absorbed, which implies that prices of assets fully reflect all available information published, therefore, no investor can make consistent returns above the average, the market level. Artificial intelligence can help make markets more efficient by analyzing vast amounts of available information to determine trends, assess sustainability risks, and estimate the benefits of potential rewards on environmentally sustainable projects. Green bond pricing models and methods for assessing investments can be improved through AI-driven analytics, leading to more effective valuation of green financial assets. When financial institutions apply AI to enhance investment practices within the green finance context, they can develop strategies that better align with market conditions and investor expectations. The use of AI in green finance would enable green financial instruments, such as green bonds, to increase pricing efficiency, thereby boosting financial performance and market efficiency.

Sustainable Development Theory

The theory of Sustainable development reinforces the need to balance economic, social, and environmental needs in achieving sustainable development goals. It advocates financial models that focus on the long-term sustainability of profits rather than immediate profits (Brundtland Commission, 1987).

Green finance, such as artificial intelligence, can facilitate the achievement of the Sustainable Development Goals (SDGs), attracting investments in renewable energy, reducing carbon impacts, and preventing environmental risks. AI-integrated green finance systems are likely to yield long-term, sustainable results, coupled with environmental sustainability, in financial institutions that incorporate their application. Artificial intelligence can help to monitor, report and enhance the effectiveness of green investments to ensure that the long-term sustainability goals set by the Sustainable Development Goals are met. The implementation of AI in green finance promotes the long-term, sustainable growth goals of financial institutions, thereby strengthening their financial capability under environmental and social guidelines.

The theoretical methodology of the research combines a range of basic concepts that could be used to clarify the relationship between AI implementation and the financial prosperity of the green finance sector. The Technology Acceptance Model (TAM) emphasizes the importance of perceived ease of use and utility in the adoption of AI, whereas the Resource-Based View (RBV) places greater emphasis on AI as a strategic asset. The stakeholder theory emphasizes the importance of ESG performance in satisfying stakeholders, while the Efficient Market Hypothesis (EMH) suggests that AI enhances market efficiency. The Sustainable Development Theory ultimately associates enduring sustainability with the use of AI. The paradigm offers an in-depth understanding of how artificial intelligence can enhance the financial outcomes of companies in the green finance sector, particularly in developing

countries like Pakistan, by augmenting decision-making, risk management, and sustainable financial behaviors.

Hypothesis Development

The ability to be innovative, follow the principles of sustainability, and respond to changes in legislation and technology are becoming major factors in a firm's performance (FP). New issues, such as the penetration of Artificial Intelligence (AI), regulation, and green finance instruments like green bonds or Environmental, Social, and Governance (ESG) scores, have been recognized as crucial value and performance drivers for companies.

AI enhances the decision-making process, operational efficiency, customer interaction, and risk management within organizations. The application of AI-powered solutions often leads to cost savings and revenue generation through the improvement of aggregates. The empirical studies showed a positive relationship between AI competencies and a firm's performance (Bughin & van Zeebroeck, 2018; Waqar et al., 2023).

H₁. The use of AI can positively influence the financial performance of companies to a considerable degree.

Effective regulation ensures market openness, protecting investors and facilitating smooth financial intermediation. Regulatory strength is also a governance tool that lowers uncertainty and risk, thereby increasing financial performance. In developing economies, strong institutions and effective enforcement are particularly important, as noted by La Porta et al. (2004).

H₂. The regulatory strength is strongly related to the financial performance of firms, with a strong positive relationship.

Green bonds and investments finance environmentally friendly projects, demonstrating a business's commitment to the environment. Green bonds could enhance corporate reputation, attract investors interested in ESG, and potentially reduce capital expenses. Scientists have studied recent publications to find that the issuance of green bonds results in increased market value and profits (Tang and Zhang, 2020; Flammer, 2021).

H₃. The issuance of green bonds will make a big difference in the financial performance of companies.

Environmental, Social, and Governance (ESG) ratings assess a firm's sustainability efforts. As ESG ratings increase, risk management, stakeholder relationships, and wealth creation become more important. Several empirical studies support that there is a positive relationship between the performance of ESG and financial performance (Khan et al., 2021; Jamal et al., 2021); Jamal et al., (2022).

H₄. The impact of the high ESG score on the financial performance of firms is positive

METHODOLOGY

Research Design

The proposed study employs a quantitative research design based on the dynamic panel Generalized Method of Moments (GMM) methodology to investigate how the adoption of Artificial Intelligence (AI) affects financial performance. Quantitative

research measures the effect of independent variables on dependent variables by using quantitative data.

Sample and Data

Digital Pakistan reports, the IT Ministry's annual reports, the State Bank of Pakistan, and the World Bank are used to collect data related to all variables. The data is based on the period from 2014 to 2023, providing an overview of developments in AI applications in green finance and regulatory frameworks. It has been identified that the choice of financial institutions and green finance products worldwide is made in areas with high green finance activity.

DESCRIPTION OF VARIABLES

Dependent Variable

The principal Variable is financial performance, which is used to determine the financial performance of firms or financial institutions. It can be measured using parameters like Return on Assets (ROA). ROA is determined as a ratio of net income to total assets. They are measures of the financial performance of organizations that implement AI technology into their green finance strategy (Zeb et al., 2025; Jamal et al., 2022, 2024).

Independent Variables

Independent variables integrated in this study were AI Adoption, Regulatory Strength, Green Bond Issuance, and ESG. The adoption of artificial intelligence technologies within financial institutions or enterprises is a measure of the extent. The adoption of artificial intelligence is determined by two key indicators: research and development and innovation (Zeng et al., 2024; Zhang & Liu, 2023).

Regulatory strength refers to the degree of government and institutional regulations and policies that support green finance. This can include measures such as promoting green bonds, implementing carbon pricing, making environmental investments, or establishing environmental reporting requirements for financial institutions. Green bond issuance refers to the total amount of green bonds issued by financial entities. Green bonds have been designed to finance projects that achieve positive environmental outcomes, such as those utilizing renewable energy sources and climate change mitigation programs. Green bonds indicate the extent to which there is a participation of the institutions involved in the green finance industry. It is projected that the issuance of green bonds will benefit its financial performance, especially among firms that utilize AI to optimize investment decisions in green projects. ESG scores indicate the degree of adherence to the Environmental, Social and Governance standards by a company (Jamal et al., 2022; Jamal et al., 2024). A higher ESG rating typically indicates a stronger commitment to sustainability and ethics in business. The independent Variable is the ESG score, which implies the effect of sustainability programs on financial performance. The correlations are expected to be favorable, and high ESG ratings can improve a company's financial performance, particularly to the extent that they utilize artificial intelligence to optimize strategies linked to ESG.

Control Variable

Carbon Footprint Reduction measures the low-carbon impact of green finance investments or the implementation of green finance projects (Zeng et al., 2024; Zhang

& Liu, 2023). It could track the reduction of carbon emissions achieved through the use of green bond-funded projects as an example.

Generalized Moment Method (GMM) Analysis

Generalized Method of Moments (GMM) is a common estimate procedure in econometrics to an econometric model where the ordinary and thus usual estimates, like the Ordinary Least Squares (OLS) measures or Maximum Likelihood estimate (MLE) cannot be used or applied efficiently. This is particularly useful when the model is endogenous or when the assumptions of homoscedasticity and normality of residuals in classical models of analysis are not valid.

GMM is a versatile and powerful estimation tool that is particularly useful when such factors as endogeneity and heteroscedasticity are present in the models. In research involving AI and green finance, GMM enables the examination of the impact of AI on financial performance while controlling for other factors and effectively addressing the issues of endogeneity. The effective application of legitimate tools, along with proper elaboration of models, is central to achieving a reliable result. This study employs a quantitative research design using a dynamic panel Generalized Method of Moments (GMM) approach to investigate the influence of Artificial Intelligence (AI) adoption on financial performance. In Quantitative research, we measure the impact of independent variables on dependent variables using numerical data.

$$FP_{i,t} = \alpha + \delta_0 FP_{i,t-1} + \delta_1 AI_{i,t} + \delta_2 RS_{i,t} + \delta_3 GB_{i,t} + \delta_4 ESG_{i,t} + \delta_5 CFR_{i,t} + \epsilon_{i,t} \tag{1}$$

Equation 1 illustrates the relationship between financial success and the adaptation of AI, as well as the impact of Regulatory Strength (RS), Green Bond Issuance (GB), ESG Score (ESG), and Carbon Footprint Reduction (CFR). The beta coefficient or δ is the slope of the relationship, and the error term is denoted by $\epsilon_{i,t}$ in that specific relationship.

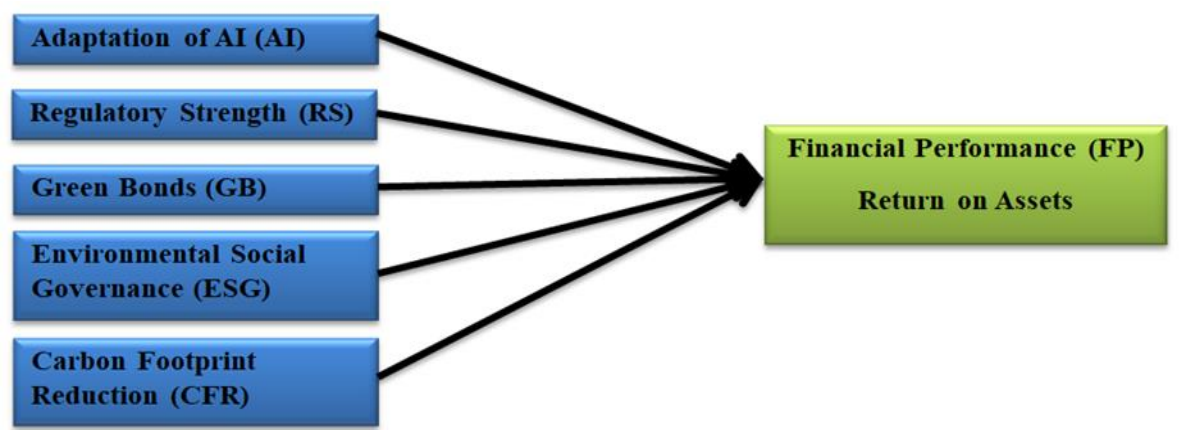


Figure 1.
Conceptual Model

DATA ANALYSIS

Table of Descriptive Statistics

This Table provides a summary of the major characteristics of the data, including the mean, standard deviation, minimum, and maximum values of the main variables.

Table 1.

Descriptive Statistics

Variable	OBS	Mean	Standard Deviation	Minimum	Maximum
FP	600	0.12	0.05	0.02	0.25
AI	600	0.65	0.15	0.10	1.00
RS	600	0.45	0.20	0.05	0.90
GB	600	1.25	0.45	0.50	2.50
ESG	600	0.78	0.10	0.50	1.00
CFR	600	5.20	2.00	1.00	10.00

The variables in Table 1 are Financial Performance (FP), AI Adoption (AI), Regulatory Strength (RS), Green Bond Issuance (GB), ESG Score (ESG) and Carbon Footprint Reduction (CFR). The mean values of FP, AI, RS, GB, ESG and CFR are 0.12, 0.65, 0.45, 1.25, 0.78 and 5.20, respectively. The minimum values of FP, AI, RS, GB, ESG and CFR are 0.02, 0.10, 0.05, 0.50, 0.50 and 1.00, respectively. The maximum values of FP, AI, RS, GB, ESG and CFR are 0.25, 1.00, 0.90, 2.50, 1.00 and 10.00, respectively.

Correlation Matrix Table

The correlation table shows the linear relationship between each pair of variables in the dataset. It is essential to understand interdependence before running GMM analysis. Correlations above 0.7 suggest a strong relationship, while values near 0 suggest weak correlations. If any two independent variables have a very high correlation, it could be problematic for GMM. Table 2 shows a positive correlation between FP, AI, RS, GB, ESG, and CFR.

Table 2.

Correlation Matrix

Variable	FP	AI	RS	GB	ESG	CFR
FP	1.000					
AI	0.450	1.000				
RS	0.350	0.600	1.000			
GB	0.400	0.700	0.510	1.000		
ESG	0.530	0.420	0.420	0.510	1.000	
CFR	0.220	0.310	0.330	0.220	0.410	1.000

GMM Estimation Results Table

This Table summarizes the results from the GMM estimation. Table 3 presents the estimated results for Pakistan with the 2-step system GMM estimator. The ROA serves as a proxy for financial performance. The lagged dependent Variable FP_{t-1} is significant and positive, indicating the dynamic character of the employed model, which is influenced by financial performance and its choices. In Model 1, AI, RS, GB, and ESG are statistically significant and positively correlated with FP. CFR and ROA have an insignificant relationship. It suggests that the adoption of AI and green finance improves financial performance in Pakistan.

AI Adoption has a positive and statistically significant impact on Financial Performance. Regulatory strength also has a positive impact, indicating that stronger regulations enhance the effectiveness of financial performance.

Table 3 illustrates the presence of negative first-order serial correlation (AR-1), whereas the second-order serial correlation (AR-2) signifies that no second-order serial correlation was identified throughout the research. The Hansen Test shows that the

instruments used in the GMM estimation are valid, which is important for the robustness of the model. The adjusted R^2 of 0.65 suggests that 65% of the variation in financial performance is explained by the model, indicating a good fit. The results indicate that there are 60 groups and 13 instruments.

Table 3.
GMM Estimation Results

Variable	FP	p-value
L.FP	0.674***	0.000
AI	0.150***	0.000
RS	0.200***	0.000
GB	0.080**	0.018
ESG	0.120*	0.058
CFR	.236	.723
Constant	0.050***	0.006
AR1	-2.58**	0.010
AR2	-0.24	0.811
Hansen	26.84	0.418
Groups Numbers	60	-
Instruments Numbers	13	-
Observations	587	-
R^2 (adj)	0.65	

The Table depicts the results of two-step system GMM for the financial performance of Pakistan. The significance levels are as follows, *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

DISCUSSION ON RESULTS

The results of this study contribute to the growing body of literature that describes the role of Artificial Intelligence (AI) in promoting green finance and improving financial performance. In this investigation, it has been found that the application of AI significantly improves the financial performance of companies that engage in green financing, particularly in developing countries like Pakistan. This discussion relates the results to theories and current studies, deciphering the implications of AI on financial performance through increasing the efficiency of investments, risk management, and sustainable innovation.

We have found evidence to support our claim that the implementation of AI in green finance enhances financial performance, leading to greater returns on investments, reduced costs, and operational efficiencies. This aligns with the Technology Acceptance Model (TAM), where the introduction of AI, perceived as a positive and user-friendly tool, leads to improved performance. A recent study, including the works of Chong, (2023) and Singh et al. (2024), supports this claim, as the studies demonstrate that AI can enhance green financing decision-making practices, particularly in portfolio management and sustainable investment practices. The ability of AI to analyze massive amounts of data and derive patterns within financial markets enables organizations to make more informed and sound decisions. This is also supported by the evidence of Brynjolfsson (2022), who argue that AI-based solutions increase operational efficiency, thereby making them more profitable and efficient. The study highlights the fact that the utilization of AI enhances the efficiency of

investments in green finance. This finding is consistent with the results of Ahmed et al., (2023), who found that AI-powered technologies, such as predictive analytics and machine learning algorithms, enable financial institutions to optimize their green investment portfolios. The ability of AI to evaluate the risk of sustainability, forecast returns on green bonds, and identifies the most favorable investment opportunities with better returns and reduced levels of risk benefits financial institutions.

Moreover, the Efficient Market Hypothesis (EMH) is based on the fact that due to AI, it is possible to promote market efficiency, which will help price green financial instruments (green bonds and ESG funds) at their best point. The study supports this view carried out by Li et al. (2025), who explain that, thanks to AI, financial institutions can analyses risks more accurately and consequently value sustainable assets best in the market. The latest studies, particularly the one presented by Kang et al., (2024), emphasize that AI enables financial institutions to develop innovative financial frameworks that yield economic and environmental benefits. In turn, these developments lead to positive financial performance, as they attract investors who seek sustainable financial solutions.

The research by Mishra & Sharma (2023), Zeng et al., (2021), and Zhang et al., (2022), proves that regulations that stimulate the use of AI in green finance establish a favorable atmosphere where financial institutions can advance their financial wellbeing due to the alignment with the national goals set regarding sustainability. Strong laws also enhance the confidence of investors, leading to better financial support for green programs. According to the latest research by Singh et al., (2024), a positive relationship exists between the usefulness of AI and financial performance. AI utilization is highly beneficial in terms of decision-making efficiency in the financial industry, particularly in sustainability and green investment decisions.

The data analysis reveals that the integration of AI in green finance holds significant importance as a driver of financial performance improvement. The findings enhance the Caribbean and real-life understanding of utilizing AI to achieve sustainable financial outcomes in underdeveloped countries, such as Pakistan. The study supports the existing literature, which has consistently demonstrated the positive impact of AI on financial performance, particularly in the area of green finance. With the increasingly high level of advancements in AI technologies, they are poised to further support the drive toward sustainability in the financial industry, introducing new opportunities for financial institutions to optimize their portfolios, better manage risks, and meet global sustainability goals.

CONCLUSION

The results of this study supplement the existing literature base, focusing on Green Finance and the power of Artificial Intelligence (AI) in enhancing financial performance. It has been found that, under the implementation of AI, the financial outcomes of organizations involved in green financing are expected to improve significantly, particularly in developing countries like Pakistan. This discussion relates the findings to theory and current studies, explaining how AI affects financial performance by improving the efficiency of investments, managing risks, and driving sustainable innovation. The fact stated in the current research confirms the increase in both financial performance and operational efficiency due to the integration of AI in green finance, as the results show an increase in investment returns and a reduction in costs. This is consistent with the Technology Acceptance Model (TAM), which suggests that improving perceptions of AI as helpful and easy to use will lead to better

results. These findings are supported by recent studies, including those by Chong et al., (2023) and Singh et al., (2024), which confirm that AI can aid the decision-making process in green finance, particularly in portfolio management and sustainable investment techniques.

The ability of AI to analyze large amounts of data and identify patterns in financial markets may enable an organization to make better, more informed, and efficient decisions. This supports the opinion of Brynjolfsson (2022), who argue that the use of AI-driven solutions promotes operational efficiency, thereby improving profitability and performance. In their study, the researchers focus on the idea that the implementation of AI enhances the efficiency of green finance investment. This aligns with the findings of Ahmed et al. (2023), who discovered that AI-based technologies, such as predictive analytics and machine learning models, can help financial institutions optimize their green investments. The ability of AI to evaluate risks in sustainability, forecast returns on green bonds, and identifies the best investment opportunities yields greater profitability and reduced risk exposure for financial institutions.

Additionally, according to the Efficient Market Hypothesis (EMH), the ability of AI to promote market efficiency can be leveraged to ensure the optimal context for green financial instruments, such as green bonds and ESG funds. The study by Li et al., (2024) supports this point of view, emphasizing that AI helps financial institutions assess risks more accurately, which allows for better pricing of sustainable assets in markets. Kang and Lee (2023), points out that AI enables financial institutions to develop innovative financial strategies that generate both economic and environmental benefits. These developments thus enhance financial performance by attracting investors seeking long-term financial solutions.

According to recent studies, such as Mishra & Sharma (2023), Zeng et al., (2021) and Zhang et al., (2022), the regulatory framework concerned with the use of AI in green finance can provide much more convenient setting of financial institutions, which can deliver better financial outcomes, complying with the national sustainability goal. Strong policies enhance investor confidence, which in turn leads to an increase in lending to green projects. More recent research, as shown by Singh et al., (2024), has demonstrated that the utility of AI positively correlates with financial performance. The adoption of AI is also a sign of a significant positive impact on the efficiency of decision-making in financial sectors, particularly in the context of sustainability and green investment decisions.

The findings underscore the significance of implementing AI in green finance to enhance financial outcomes. These insights enhance the theoretical and empirical understanding of how AI can be utilized to promote sustainable financial outcomes in a country like Pakistan, which is underdeveloped. Indeed, the research confirms contemporary literature, which consistently portrays the positive impacts of AI on financial performance, particularly in green finance. AI technologies are becoming increasingly advanced, and thus their ability to drive the financial industry towards a more sustainable direction will likely grow, providing financial institutions with new tools to optimize their portfolios, enhance risk management, and align with global sustainability goals.

STUDY IMPLICATIONS

The results in this paper have more practical implications for financial institutions, politicians, and investors, particularly in developing countries like Pakistan, where artificial intelligence and green finance are still in their infancy stage. The research recommends that the government take further action to ensure stronger green finance regulations and encourage financial institutions to continue adopting AI for the optimization of their green investments. Future studies can investigate the long-term impact of AI in green finance and its potential to evolve in response to global sustainability goals (SDGs) and the dynamics of the financial market.

STUDY LIMITATIONS

Despite the importance of the study, there are still weaknesses in this paper. Scarcity of detailed, publicly available information on green finance products on AI and the results in environmental impact. The results may be inapplicable to all industries and companies and may be restricted to those that have been part of the sample. The operations of the study, which utilize AI models, are place-bound to the availability of clean and proper data, which may not always be available in the community of environmental finance.

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